Inside StarCore

Everyone knows that Nuclear Power is scary... even if the reasons for it are not well understood. There is an interesting book on this topic by Spencer R. Weart, called "Nuclear Fear", which attributes this perception to deliberate propaganda efforts by various nations and agencies over the years since the Second World War. The general theme of the book is that it suited the two big powers to foster this perception because it supported the general intent of the nuclear weapon buildup then in progress. Whether or not this is actually true is fairly moot but the perception that nuclear power is intently dangerous is well established. So to help dispel this perception I thought it would be interesting to explore the design and inner workings of the StarCore plant, take a look at what drives the specifications, and make some pretty broad brush predictions about the safety of both the plant design and the overall nuclear fuel cycle.

StarCore is a development of the High Temperature Gas Reactor design initially started at the Atomic Energy Research Authority in the United Kingdom in 1956. Since then many different versions of the design have been operated by various nations; however the design of the pebble-fuel, helium-cooled variant used by StarCore was established in Germany in 1966 where it operated successfully for 21 years before succumbing to political agendas. It is this design that has been called "inherently safe" by the International Atomic Energy Authority. This is a significant statement by a very knowledgeable agency, especially when juxtaposed with the general public perception of nuclear power. Now nuclear fuel is very powerful stuff; it has more than two millions times as much energy, gram for gram, as gasoline. This, of course, is a very good thing when we consider we will have to power a planet with 9 billion people on it in the near future.

In most of the world the design for any new nuclear power plant has been based on some type of light water reactor, since only this type was considered to be acceptable to the regulating authorities. Canada was different and started development of the unique CANDU (CANadian Deuterium Uranium) design in 1954 which has proven very successful. But for the vast majority of nuclear power plants the business plan has to be written around the realities of the light water reactor design, and this causes some compromises to be made in both operations and the end-to-end fuel cycle, resulting in the need to store used fuel - still with over 95% life remaining - in water-filled cooling ponds at the reactor sites. Sixty-five thousand tons of it in the United States alone. And it was this used fuel that was responsible for much of the radiation released in the Fukushima disaster. But despite Chernobyl and Fukushima the light water reactor type of nuclear power plant has been one of the most reliable and safe forms of power ever invented - with less loss of life and less pollution than any other source. It must be clear, though, that although the present light water reactor is very safe, an "inherently safe" StarCore design would be even better. And the reason that StarCore is inherently safe makes for a good story, I think.

Nuclear reactions power the universe, and at the heart of every star is a source of nuclear power (hence the name of our company). In a standard nuclear reactor energy is produced when the natural decay of nuclear fuel results in the emission of neutrons, which in turn causes further fuel atoms to split, in a process known as fission. Under the right conditions the process will continue and generate a lot of energy. StarCore uses uranium-238 as fuel, which was formed when the world condensed out of the clouds of interstellar matter billions of years ago; over the millennia the heat from this nuclear fuel has transformed the world into a home suitable for the growth of our species.

Uranium-238, as mined in it's natural state, contains about 0.7 % of another form of uranium - uranium-235. In most reactors (CANDU is an exception) the uranium-235 must be concentrated to 3 or more percent of the total in order to provide sufficient neutrons to strike other uranium atoms and initiate the fission process. Now not any neutrons will do the trick - they have to be slow neutrons. Fast neutrons whizz past the uranium-235 without doing much, and they have to be slowed down in the core in order to cause the uranium to split and release the neutrons and energy.

Now the hotter the fuel gets, the faster the released neutrons and the less fission that occurs. When the temperature reaches around 1000 deg C, the neutrons are so fast that there is very little fission occurring and the reaction enters a stable state. This is called a "negative thermal gradient" and it means that the reactor is self-limiting - it just cannot get hot enough to get into trouble. A standard light water reactor is unable to use this principle since the maximum allowable temperature is much lower - around 400 deg C. The maximum operating temperature of the StarCore design is 1600 deg C so there is a huge safety margin built in. And the uranium fuel is sealed using three layers of high temperature ceramic and carbon coating into microspheres less than 1 millimeter in diameter - about the size of a thick pencil lead - and these are then formed into cuboctahedrons (like cubes with the corners cut off) 60 millimeters wide. The uranium cannot be extracted for terrorist purposes, and no radioactive material can ever escape from the microspheres. The coating used is really very, very, strong - you can see similar materials in use on missile nosecones and other critical high temperature applications.

This high temperature design and resultant stable, self limiting, operating characteristics, together with the extremely tough fuel containment coating, are the two main reasons that the High Temperature Gas Reactor is considered "inherently safe" under all conditions. Even under the worst imaginable catastrophes, the StarCore plant can only enter a stable condition and the fuel cannot fail or melt due to high temperatures, and this was the reason that the phrase "inherently safe" was adopted by the International Atomic Energy Agency in their Technical Document 1674 "Advances in High Temperature Gas Cooled Reactor Fuel Technology" to describe this design.

So how much energy does it make if it ever enters this safe state? Around 600 kW, or about the same as two SUV engines. You can see how much radiator area these require by looking under the hood of your car... not much; and not enough heat can ever be radiated to cause difficulties under any circumstances.

So the StarCore plant cannot fail in any usually accepted sense, but what about the fuel and the refueling process? Surely there must be the possibility of accidents and contamination during refueling, and what are we going to do with the used fuel? I mentioned earlier that our Business Plan drives the design of our reactor, and this has allowed us to take a no-compromise approach to the whole plant and fuel cycle. StarCore will not sell the plants - they remain our property throughout their life. We are responsible for both operations and decommissioning. And we will not refuel them on-site - the sealed reactor unit will be replaced with a new one after five years, to insure safety is not compromised and our sites remain completely pristine and free from stored used fuel. The reactors will be returned to the main StarCore plant for refueling and we intend to reprocess the fuel under controlled conditions. StarCore; inherently safe, clean, green; water and power: something worth pursuing I think.

We are StarCore, and we have a Vision.

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